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(54) Network topology management system

(57) A system and method for maintaining complex relationships between computer network elements provides a common database for storing node, type, and view data. The views are created and maintained by the network management system. When a new node is added or parentage of a node is changed, the views of a node are modified in a network database.

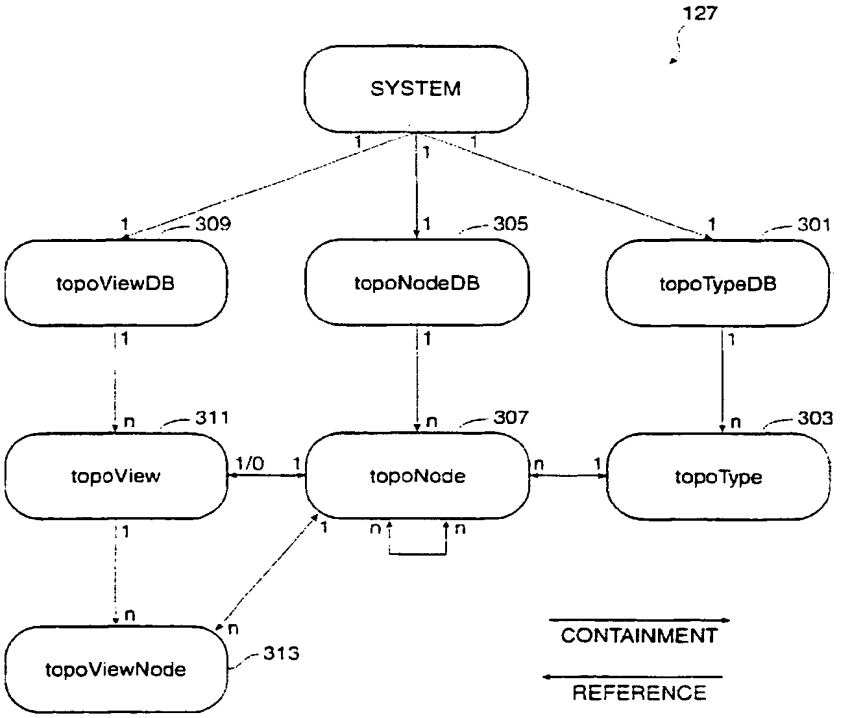

FIG. 3

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Description

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The present invention relates to the field of computer systems and their management and control. More specifically, in one particular embodiment the invention provides a method and device for managing and visualizing the topology of a computer network.

As computer networks have developed and achieved wide acceptance, it has become necessary for managers of such networks to have access to software and hardware tools necessary to manage, monitor and control networks. As networks have increased in complexity, so have the tools needed for their management. Existing management packages for managing a network provide a wide range of functionality including network management application launchers, event request and filtering mechanisms, logging systems for storing network event and performance statistics, alarm correlation mechanisms, load balancing mechanisms, and other tools. Among the most advanced of such packages is SunSoft's Solstice Enterprise Manager 1.1. Other systems include Hewlett Packard's OpenView platform Network Node Manager, Operations Center and AdminCenter; and IBM's NetView.

The most advanced of such packages allow multiple operators to access management information simultaneously and support multiple computing environments. To facilitate this complex functionality advanced network management systems have used an object oriented network model. Network resources represented as objects are stored and manipulated by management applications and agents. The use of such object oriented approaches enables, *inter alia,* much easier scalability and other advantages. In addition, the support of multiple network management protocols is facilitated. In SunSoft's Solstice products for example, the management tools may be distributed over multiple workstations. The same information is made available to all applications and tools via MISs ("Management Information Servers").

Such systems have met with substantial success and are, in fact, considered to be pioneering in the industry. However, certain challenges remain. For example, while the object oriented approach to network database management has proven successful certain limitations remain. Such systems have, previously, maintained separate databases representing the logical and physical layouts of a network, respectively. Separate applications in the network management system then access and may modify the logical and physical topology databases. In some instances it has been found that two views of the same network can be found to be inconsistent as a result of this architecture.

According to one aspect of the invention, there is provided a computer network comprising a plurality of network nodes and interconnections; a network management system comprising a database of managed network resources, the database of managed network resources defining network nodes, associated node types and associated views of the nodes; and a plurality of network management users, the network management users being arranged to display views of the network using said network management database. In one embodiment, through user modification of node attributes, the views of the network are updated by the system through use of an object oriented database. In a preferred embodiment the views of the network are modified based on input or change of the attributes of the nodes. For example, parent relationships may be used to define a new view node when a new parent is added to an attribute of a node.

It is thus possible to provide improved tools for maintaining, viewing and managing the physical and logical topology of a network. The system can maintain databases for both logical and physical topology using an improved data model. Consistency can be maintained by placing a consistency application in a logical/physical database. In a preferred embodiment, users are able to access the data only through the physical topology database; both physical and logical topology resides in an MIS database.

Other aspects of the invention are exemplified by the attached claims.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Fig. 1 is an overall view of a hypothetical network, showing the relationship to the network management tools described herein;

Fig. 2 is a typical screen display provided by one embodiment of the invention;

Fig. 3 is an object relationship diagram according to one specific embodiment of the invention;

Figs. 4A to 4C illustrate a simple application of the invention;

Figs. 5A to 5D illustrate specific data structures used therein; and

Figs. 6A to 6C illustrate use of the invention in specific examples.

Fig. 1 illustrates a computer network along with its associated network management system. As shown, the computer network 100 will include hardware such as hosts 101a, 101b, 101c, 101d, and 101e, routers 103, and subnetworks

100a and 100b. Hosts 101 may be, for example, users, servers and other network elements. Attached to one or more of the hosts are network management elements 109. Management elements 109 will be connected to one or more of the network hosts for network managers to monitor and control the network.

The layout of the network is illustrated with regard to physical connectivity. but another set of relationships will also exist. That is, the various elements of the network will also be related by logical relationships. For example, a portion of the users connected to servers 101a and 101b may be in one logical group. while other portions of the network will be in other logical groups. Often it is desirable for network managers to be able to view the network in logical views other than the physical layout of the network. The embodiment now to be described includes an improved viewer mechanism for looking at and analyzing various portions of the network.

A management system or "nerve center" 111 is provided in the network to manage and control the network. While the management system 111 is illustrated as a single entity on the network, it may in many embodiments be distributed over multiple workstations and servers.

The management system includes an MIS or Management Information Server 113. The MIS is an object oriented network model that enables object definitions to be stored and manipulated by management applications 115, using object oriented tools such as classing, inheritance and scoping to represent complex resources and simplify complex operations. Management applications 115 interact through the network MIS rather than with each other.

System 111 will normally include a set of standard tools such as a relational database logging tool. alarm managers and other tools. The system is able to provide access to managed objects via a common management information protocol (CMIP) with management protocol adapter 119. Other system elements are supported directly through an interface such as a protocol driver manager (PDM) in the case of, for example, SunNet Manager Agent interactions.

As shown in Fig. 1, a particular user of the system will have applications 115 resident on his/her particular server or workstation. In addition, the use] may have various tools 121, a particular graphical user interface 123 and viewer 125. The various application utilize the resources of the nerve center to perform management tasks. A database 127 in the nerve center provides a single source of network objects in an object oriented relational database to service th various network applications for management of the network. The system illustrated in Fig. 1 will, in a preferred embodiment, be based on the Solstice Enterprise Manager 1.1, available from Sun Microsystems, Inc. The various software and data elements discussed herein are stored on a memory device 128 such DS one or more magnetic or optical disc drives.

Fig. 2 illustrates a typical screen display available to a user of the network management system disclosed herein. As shown, the system will display a viewer 201 in which the topology of the system (logical or physical) may be displayed. In addition, the system may display other items of interest such as an alarm report 203.

Both the logical and physical elements of the network model are stored in a common database 127. Fig. 3 illustrates the architecture of the network database 127 according to a preferred embodiment of the invention. The purpose of the topology database is to store topological information about the managed networked environments. Topological information is in the form of objects which represent topological nodes, views, viewnodes, and types. The topology database includes data of the following types: a topoTypeDB, a topoNodeDB, and a topoViewDB. These data are used by the system applications to manage the user's networks.

topoTypeDB

The topoTypeDB object class 301 contains the general relationship or rules between objects (which represent a topoType 303). In other words, topoTypeDB contains a list of object types. Examples of such object types would be servers, routers, hubs, and users.

The topoTypeDB is a managed object class that acts as a "container" for all topoType objects. The topoTypeDB object class is named under the system object and only one instance of a topoTypeDB object class can be created under a system. TopoType is an object class that is named under the topoTypeDB object class.

topoNodeDB

The topoNodeDB object class 305 contains a flat layout of the objects in the particular managed networked environment, that is, lists of all nodes 307 in the network and their attributes.

The topoNodeDB is a managed object class that acts as the "container" for all topoNode objects. This object class lists all nodes and their attributes. The topoNodeDB object class is named under the system object and only on instance of the topoNodeDB object class can be created under a system.

TopoNode is an object class that is named under the topoNodeDB object class. The topoNode object class has the following featur s. TopoNode can be positioned in multiple views. This attribute is allowed since the behaviour of "topoTypeLegalChildr n" is checked for all parents specified by the attribute. The ASN1 syntax of topoNodeParents is a set of topoNodeId's. Special secondary index queries can be done with actions. TopoNod objects can be renamed.

The topoNodeName attribut is uniqu across all topoNod s under the same topoNode DB. The reason that topoNodeName is not used as the naming attribute is to allow renaming of topoNode objects. If a topoNode object is renamed, it's new name cannot be the same as the name of an existing node.

A topoNodeChildren attribute is a reverse relationship attribute of a topoNodeParents attribute. It specifies all the topoNode children that are contained by this topoNode. Propagation severity of topoNode objects can be tracked and propagation can be controlled such that, for example, alarms are indicated in desired views.

Each node has an associated severity, derived from alarms posted for the corresponding resource. The tracking of the propagated severity is performed with a "topoNodePropagateSeverity" attribute. This attribute is the maximum value of the topoNodeSeverity of the topoNode and the topoNodePropagateSeverity of all its children.

To control propagation locally, a topoNode's "topoNodePropagateUp" attribute is used. To turn the propagation off for the entire topology database, the topoNodeDB's "topoStatePropagation" attribute is used. By default, the global propagation flag is set on. A topoNode propagates its current severity to its parents only if its topoNodePropagateUp flag is on and topoNodeDB's topoStatePropagation flag is on.

topoViewDB

The topoViewDB 309 object class contains views of the objects in the managed networked environment, that is, of all views 311. The various views contain logical groups of network resources or topology nodes that a user may wish to use for management purposes. For example, a view of various ethernet servers in a network may be desired to monitor the failure rate of such servers. Thus, a view of such servers will be formed.

TopoViewDB is a managed object class that acts as the container for all topoView objects. TopoViewDB lists all views; each of these views is called a topoView. The topoViewDB object class is named under the system object and only one instance of the topoViewDB object class can be created under a system. A view is a graphical representation of a set of related managed objects. For example, in a network that contains multiple subnetworks, the network might be one view that has subnetwork elements and each subnetwork within it might constitute or use separate views.

TopoView is an object class that lists views and is named under the topoViewDB object class. Each topoVi w object is called a topoViewNode. Each instance of the topoView class represents a view in an executable viewing program (em_viewer in the case of SunSoft) to display objects that are in the view and store attributes that are related to the view. TopoView objects show relationships and hierarchy between objects. Instances of the class are named under topoViewDB, but create/delete operations are not supported by the name binding.

The topoViewNode objects 313 represent topoNode objects in different views (different logical views). Each topoViewNode object is associated with a topoNode object. There is a many-to-one relationship between topoViewNode and topoNode objects. If the information is available in the topoViewNode's associated topoNode object, the information is not duplicated in the topViewHode object. The exception is that the topoNodeId attribute is used as the naming attribute to create topoViewNode objects.

Since instances of the class are named under topoView, create/delete operations are not supported by the name binding. All topoViewNode objects are created/deleted as side effects of creating/deleting topoNodes and adding/removing parents to form a "topoNodeParents" attribute of topoNode objects. The MIS is responsible for maintaining the referential integrity between topoViewNode and topoNode objects (for example, a topoNode can contain other topoNodes).

TopoViewNode objects are automatically updated. When a new parent is added to the topoNodeParents attribute, the MIS creates a topoViewNode object associating to the topoNode under a topoView object which associates to the new parent. When an old parent is removed from topoNodeParents, the MIS deletes the topviewNode object associating to the topoNode from the topoView object which associates to the old parent. If the user wants to move or place a topoNode in a different or another view, it will be necessary to change the topoNode's topoNodeParents attribute.

Data integrity between topoNode, topoView, and topoViewNode is maintained by the system. Data integrity is maintained by the behaviour, in the system herein, of the class. Once a new topoNode is created, if the type of the topoNode can contain other topoNodes, the MIS will create a topoView object associated to the topoNode. If a topoNode is deleted, all topoView and topoViewNode objects associated with the topoNode are automatically removed by the MIS.

Fig. 3 includes a description of the containment of the various objects in the database. Specifically, TopoViewDB, topoNodeDB, and topoTypeDB are contained within the "system." A topoView is contained within the topoViewDB. A topoViewNode is contained within a topoView. A topoNode is contained within the topoNodeDB. A topoType is contained within the topoTypeDB.

The reference rules for the databas are as follows. A topoView must r f r nc a topoNode. Only one topoVi w can r ferenc a singl topoNode. A topoViewNode must ref rence a topoNode. On or more topoVi w Nodes can referenc a single topoNode. A topoNode can ref rence other topoNodes as topoNodeParents or topoNod Children. A topoNode must ref rence one topoType. A topoType can b refer nced by multiple topoNodes.

Table 1 provides general descriptions of topology types.

Table 1

Topology Type	Description
Container	A generic view representation.
Universe	A generic view. generally used at the top level.
Internet	Any combination of IP networks.
Subnetwork	Containers specific to the Internet.
Host	An IP device on a network.
Device	A general representation of a network element.
Link	A physical connection between two network elements.
Router, Bridge Hub	Multiple interface devices capable of transferring packets between networks.

Figs. 4A to 4C illustrate various views of a network using the system herein, Fig. 4A illustrates a view of several routers 401 in a network. Fig. 4B illustrates a new view that has been created including only two of the routers that a particular user desired to monitor. Fig. 4C illustrates the display after using the system to add another router to the view. Of course, the layout of networks is most often quite complex and Fig. 4 shows only a simple illustration.

Figs. 5A to 5D illustrate the data formats and contents of a particular topoType (Fig. 5A), topoNode (Fig. 5B), topoView (Fig. 5C), topoViewNode (Fig. 5D). Of interest, in topoNode, the topoNodeChildren entry (and, not shown, parents) is changed upon change or deletion of, e.g., a parent or other relevant attribute.

Fig. 5A illustrates the data structure for a topoType. Fig. 5B illustrates a topoNode entry. Fig. 5C illustrates a particular topoView entry. Fig. 5D illustrates the topoViewNode entry for node 13 in Fig. 5B.

The definition of all objects is preferably in GDMO (Guidelines for Definition of Managed Objects) format. The definitions according to one embodiment are shown in the file "topo.gdmo" below. The syntax for GDMO objects is defined in ASN.1. The file "topo.asnl", set out later, provides object syntax according to one specific embodiment of the invention.

Example

Figs. 6A to 6C illustrate typical use of the present embodiment. A user typically identifies objects such as routers, hubs, bridges, print servers, NFS servers, and WAN links that have an impact on the greatest number of users on the network. The typical user will then monitor only those devices, reducing the number of managed objects to create and monitor.

In the system herein a view of the network can include part (or all) of a network topology or it can simply be an arbitrary collection of managed objects, not part of the topology. In a small scale network, one might wish to place all the critical nodes into a single view of the network, as shown in Fig. 6A. In this example, a network includes two subnets (A and B), which are connected by a router.

For most network configurations it will be useful to have multiple views of the network to represent functional groupings of network devices and to represent the network topology. Using the database model discussed above, one might want, for example, to depict devices in particular buildings, or a view that consists only of routers. Taking the example in Fig. 6A one might want to create a separate view for each subnet as well as separate views by type of device (routers, NFS servers, and print servers). A user would create these views one element at a time using a graphical user interface, which would then build the database elements discussed above. As an example, views grouping elements by function (software servers, routers, and print servers) and subnetwork(s) might be formed as shown in Fig. 6B. A high level view is shown in Fig 6C. As shown therein, cloud icons represent the separate views that have been created. By double clicking on the clouds, one would then see the elements within these views of the network. Of course, the same element may appear in multiple views. For example, a particular server could occur in both a "servers" view as well as the Net_B view, which shows all of the nodes in that subnetwork.

The above description is illustrative and not restrictive. Many variations of the invention will become apparent to those of skill in the art upon review of this disclosure. Merely by way of example specific database relationships hav been used for illustration, but the invention is not so limited.

topo.gdmo

```
MODULE "EM Topology"

-- OBJECT CLASS
topoNode MANAGED OBJECT CLASS
      DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992" : top;
      CHARACTERIZED BY
            topoNodePackage;
      REGISTERED AS { em-topo-objectClass 1 };

topoNodePackage PACKAGE
      BEHAVIOUR topoNodePackageDefinition BEHAVIOUR DEFINED AS
            !This managed object class represent a single node in the topo
            graph.  A node is anything in the network which can be connected
            to another thing:  a device, a part of a device, an interface, a
            cable, etc.

            Once a new topoNode is created, if the type of the topoNode can
            contain other topoNodes, the system will create a topoView object
            associated to the topoNode.

            If a topoNode is deleted, all topoView and topoViewNode objects
            associated to the topoNode are automatically removed.

            The topoNodeName attribute is unique across all topoNodes under
            the same topoNodeDB.  The reason that topoNodeName is not used
            for naming attribute is to allow renaming of the object.

            The topoNodeParents attribute is a relationship attribute.  It is
            used to specify the parent topoNodes which contain this topoNode.
            Note the containment relationship is a many-to-many
            relationships.  It is different than the standard OSI MIT
            containment relationship, which is a one-to-many relationship.
            The many-to-many relationship provides the flexibility by which
            the user can position the same topoNode into different views.

            When a new parent is added to the topoNodeParents attribute, the
            system creates a topoViewNode object associating to the topoNode
            under the topoView object which associates to the new parent.

            When an old parent is removed from the topoNodeParents attribute,
            the system delete the topoViewNode object associating to the
            topoNode from the topoView object which associates to the old
            parent.

            The topoNodeChildren attribute is a reverse relationship
            attribute of the topoNodeParents attribute.  It is used to
            specify the children topoNodes contained by this topoNode.
            !;
      ;
      ATTRIBUTES
            topoNodeId GET,
            topoNodeName GET-REPLACE,
            topoNodeType GET-REPLACE,
            topoNodeMOSet
                  DEFAULT VALUE EM-TOPO-ASN1.emptyTopoNodeMOSet
                  GET-REPLACE,
            topoNodeCmipAgentMO
                  DEFAULT VALUE EM-TOPO-ANS1.nullTopoNodeMO
                  GET-REPLACE,
            topoNodeRpcAgentMO
            topoNodeGetByType,
            topoNodeGetByMO,
```

```
            topoGetViewGraph;
      NOTIFICATIONS
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  objectCreation,
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  object Deletion;
      ;

topoType MANAGED OBJECT CLASS
      DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992" : top;
      CHARACTERIZED BY
            topoTypePackage;
      REGISTERED AS { em-topo-objectClass 3};

topoTypePackage PACKAGE
      BEHAVIOUR topoTypePackageDefinition BEHAVIOUR DEFINED AS
            ! This managed object class specifies schema information that
            defines how the Topology database can be constructed.";
      ;
      ATTRIBUTES
            topoTypeId GET,
            topoTypeDerivedFrom GET,
            topoTypeAllDerivedFrom GET,
            topoTypeBaseOf GET,
            topoTypeMaxVisibleLevel
                  DEFAULT VALUE EM-TOPO-ASN1-defaultMaxVisibleLevel GET,
            topoTypeMaxTopoLevel
                  DEFAULT VALUE EM-TOPO-ASN1.defaultMaxTopoLevel GET,
            topoTypeLegalAcrs
                  DEFAULT VALUE EM-TOPO-ASN1.defaultTopoTypes
                  GET ADD,
            topoTypeAllLegalArcs GET,
            topoTypeLegalChildren
                  DEFAULT VALUE EM-TOPO-ASN1.defaultTopoTypes
                  GET ADD,
            topoTypeAllLegalChildren GET,
            topoTypeDrawMethod
                  DEFAULT VALUE EM-TOPO-ASN1.defaultDrawMethod
                  GET-REPLACE
            ,
            topoTypeDefaultLayer GET-REPLACE
            ;
      NOTIFICATIONS
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  objectCreation,
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  object Deletion,
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  attributeValueChange;
      ;

topoTypeDB MANAGED OBJECT CLASS
      DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992": top;
      CHARACTERIZED BY
            topoTypeDBPackage;
      REGISTERED AS { em-topo-objectClass 4 } ;

topoTypeDBPackage PACKAGE
      BEHAVIOUR topoTypeDBPackageDefinition BEHAVIOUR DEFINED AS
            ! This managed object class acts as the container for all
            topoType-related objects.!;

                  DEFAULT VALUE EM-TOPO-ASN1.nullTopoNodeMO
                  GET-REPLACE,
```

```
                topoNodeSmnAgentMO
                      DEFAULT VALUE EM-TOPO-ASN1.nullTopoNodeMO
                      GET-REPLACE,
                topoNodeDefaultMO
                      DEFAULT VALUE EM-TOPO-ASN1.nullTopoNodeMO
                      GET-REPLACE,
                topoNodeParents GET-REPLACE ADD-REMOVE,
                topoNodeChildren GET,
                topoNodePeers GET-REPLACE ADD-REMOVE,
                topoNodeManaged GET-REPLACE,
                topoNodeIsManaged GET,
                topoNodeState GET-REPLACE,
                topoNodeSeverity GET-REPLACE,
                topoNodePropagatedSeverity GET,
                topoNodePropagateUp
                      DEFAULT VALUE EM-TOPO-ASN1.topoBooleanTrue
                      GET-REPLACE,
                topoNodeDisplayStatus
                      DEFAULT VALUE EM-TOPO-ASN1.emptyTopoNodeDisplayStatus
                      GET-REPLACE ADD-REMOVE,
                topoNodeGeoLocation
                      DEFAULT VALUE EM-TOPO-ASN1.nullGeoLocation
                      GET-REPLACE,
                topoNodeLayer
                      DEFAULT VALUE EM-TOPO-ASN1.emptyLayer
                      GET-REPLACE,
                topoNodeUserData
                      DEFAULT VALUE EM-TOPO-ASN1.emptyUserData
                      GET-REPLACE
                ;
          NOTIFICATIONS
                "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                objectCreation,
                "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                objectDeletion,
                "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                attribtueValueChange;
          ;
    topoNodeDB MANAGED OBJECT CLASS
          DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992" : top;
          CHARACTERIZED BY
                topoNodeDBPackage;
          REGISTERED AS { em-topo-objectClass 2 };

    topoNodeDBPackage PACKAGE
          BEHAVIOUR topoNodeDBPackageDefinition BEHAVIOUR DEFINED AS
                !This managed object class acts as the container for all
                topoNode-related objects.!;
          ;
          ATTRIBUTES
                topoNodeDBId GET,
                topoAllStatus
                      DEFAULT VALUE EM-TOPO-ANS1.emptyTopoAllStatus
                      GET-REPLACE ADD-REMOVE,
                topoAllLayer
                      DEFAULT VALUE EM-TOPO-ASN1.emptyTopoAllLayer
                      GET-REPLACE ADD-REMOVE,
                topoStatePropagation
                      DEFAULT VALUE EM-TOPO-ASN1.topoBooleanTrue
                      GET-REPLACE,
                ;
          ACTIONS
                topoNodeGetByName,
          ;
```

```
        ATTRIBUTES
              topoTypeDBId GET;
        NOTIFICATIONS
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    objectCreation,
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    objectDeletion;
        ;

  topoView MANAGED OBJECT CLASS
        DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992" top;
        CHARACTERIZED BY
              topoViewPackage;
        REGISTERED AS { em-topo-objectClass 5 };

  topoViewPackage PACKAGE
        BEHAVIOUR topoViewPackage Definition BEHAVIOUR DEFINED AS
              !This managed object class is used to store information for the
              topological view application.!;
        ;
        ATTRIBUTES
              topoNodeId GET,
              topoViewBackgroundImage
                    DEFAULT VALUE EM-TOPO-ASN1.defaultBackgroundImage
                    GET-REPLACE,
              topoViewMapConfigFile
                    DEFAULT VALUE EM-TOPO-ASN1.defaultMapConfigFile
                    GET-REPLACE,
              topoViewMapInitialGeoArea
                    DEFAULT VALUE EM-TOPO-ASN1.defaultMapInitialGeoArea
                    GET-REPLACE;
        NOTIFICATIONS
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    objectCreation,
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    objectDeletion,
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    attributeValueChange;
        ;

  topoViewDB MANAGED OBJECT CLASS
        DERIVED FROM "Rec. X.721 | ISO/IEC 10165-2 : 1992" : top;
        CHARACTERIZED BY
              topoViewDBPackage;
        REGISTERED AS { em-topo-objectClass 6 };

  topoViewDBPackage PACKAGE
        BEHAVIOUR topoViewDBPackageDefinition BEHAVIOUR DEFINED AS
              !This managed object class acts as the container for all
              topoView-related objects.!;
        ;
        ATTRIBUTES
              topoViewDBId GET,
              topoViewNodeAutoPosition
              DEFAULT VALUE EM-TOPO-ANS1.topoBooleanTrue
              GET-REPLACE
        ;
        NOTIFICATIONS
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    objectCreation,
              "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                    objectDeletion;
        ;
```

```
topoViewNode MANAGED OBJECT CLASS
      DERIVED FROMRec. X.721 | ISO/IEC 10165-2 : 1992" : top;
      CHARACTERIZED BY
            topoViewNodePackage;
      REGISTERED AS { em-topo-objectClass 7 };

topoViewNodePackage PACKAGE
      BEHAVIOUR topoViewNodePackageDefinition BEHAVIOUR DEFINED AS
            !This managed object class is used to store information for the
            topological view node.";
      ;
      ATTRIBUTES
            topoNodeId GET,
            topoViewNodePosition GET-REPLACE;
      NOTIFICATIONS
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  objectCreation,
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  objectDeletion,
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" :
                  attribtueValueChange;
      ;

-- Name Bindings

topoNodeDB-system NAME BINDING
      SUBORDINATE OBJECT CLASS topoNodeDB;
      NAMED BY
      SUPERIOR OBJECT CLASS
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" : system AND SUBCLASSES;
      WITH ATTRIBUTE topoNodeDBId;
      BEHAVIOUR topoNodeDB-systemBehaviour
            BEHAVIOUR DEFINED AS
            !This name binding defines the location of the topoNodeDB
            object.!;
      ;
      CREATE
      DELETE ONLY-IF-NO-CONTAINED-OBJECTS;
      REGISTERED AS { em-topo-binding 1 };

topoTypeDB-system NAME BINDING
      SUBORDINATE OBJECT CLASS typoType DB;
      NAMED BY
      SUPERIOR OBJECT CLASS
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" : system AND SUBCLASSES;
      WITH ATTRIBUTE topoTypeDBId;
      BEHAVIOUR topoTypeDB-systemBehaviour
            BEHAVIOUR DEFINED AS
            !This name binding defines the location of the topoTypeDB
            object.!;
      ;
      CREATE;
      DELETE ONLY-IF-NO-CONTAINED-OBJECTS;
      REGISTERED AS { em-topo-binding 2 };

topoViewDB-system NAME BINDING
      SUBORDINATE OBJECT CLASS topoViewDB;
      NAMED BY
      SUPERIOR OBJECT CLASS
            "Rec. X.721 | ISO/IEC 10165-2 : 1992" : system AND SUBCLASSES;
      WITH ATTRIBUTE topoViewDBId;
      BEHAVIOUR topoViewDB-systemBehaviour
            BEHAVIOUR DEFINED AS
            !This name binding defines the location of the topoViewDB
```

```
            object.!;
        ;
        CREATE
        DELETE ONLY-IF-NO-CONTAINED-OBJECTS;
        REGISTERED AS { em-topo-binding 3 };

topoNode-topoNodeDB NAME BINDING
        SUBORDINATE OBJECT CLASS topoNode;
        NAMED BY
        SUPERIOR OBJECT CLASS topoNodeDB;
        WITH ATTRIBUTE topoNodeId;
        BEHAVIOUR topoNode-topoNodeDBBehaviour
              BEHAVIOUR DEFINED AS
              !This name binding defines the location of topoNode objects.!;
        ;
        CREATE WITH-AUTOMATIC-INSTANCE-NAMING;
        DELETE ONLY-IF-NO-CONTAINED-OBJECTS;
        REGISTERED AS { em-topo-binding 4 };

topoType-topoTypeDB NAME BINDING
        SUBORDINATE OBJECT CLASS topoType;
        NAMED BY
        SUPERIOR OBJECT CLASS topoTypeDB;
        WITH ATTRIBUTE topoTypeId;
        BEHAVIOUR topoType-topoTypeDBBehaviour
              BEHAVIOUR DEFINED AS
              !This name binding defines the location of topoType objects.!;
        ;
        CREATE
        DELETE ONLY-IF-NO-CONTAINED-OBJECTS;
        REGISTERED AS { em-topo-binding 5 };

topoView-topo-ViewDB NAME BINDING
        SUBORDINATE OBJECT CLASS topoView;
        NAMED BY
        SUPERIOR OBJECT CLASS topoViewDB;
        WITH ATTRIBUTE topoNodeId;
        BEHAVIOUR topoView-topoViewDBBehaviour
              BEHAVIOUR DEFINED AS
              !This name binding defines the location of topoView objects.
              This name binding doesn't support create and delete management
              operations.!;
        ;
        REGISTERED AS { em-topo-binding 6 };

topoViewNode-topoView NAME BINDING
        SUBORDINATE OBJECT CLASS topoViewNode;
        NAMED BY
        SUPERIOR OBJECT CLASS topoView;
        WITH ATTRIBUTE topoNodeId;
        BEHAVIOUR topoViewNode-topoViewBehaviour
              BEHAVIOUR DEFINED AS
              !This name binding defines the location of topoViewNode objects.
              This name binding doesn't support create and delete management
              operations.!;
        ;
        REGISTERED AS { em-topo-binding 7 };

-- Attributes

topoAllLayer ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoAllLayer;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoAllLayerBehaviour BEHAVIOUR DEFINED AS
```

```
            !This attribute identifies the list of allowed layer for
            t poNodeLayer.!;

      ;
      REGISTERED AS { em-topo-attribute 1 };

topoAllStatus ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoAllStatus;
      MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
      BEHAVIOUR topoAllStatusBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the list of allowed display status for
            topoNodeDisplayStatus.!;
      ;
      REGISTERED AS { em-topo-attribute 2 };

topoNodeChildren ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodes;
      MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
      BEHAVIOUR topoNodeChildrenBehaviour BEHAVIOUR DEFINED AS          AS
            !This attribute contains a list of all topoNode objects which are
            logically children of this topoNode object.!;
      ;
      REGISTERED AS { em-topo-attribute 3 };

topoNodeCmipAgentMO ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeMO;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeCmipAgentMOBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the CMIP agent object that is
            represented by this topoNode object.!;
      ;
      REGISTERED AS { em-topo-attribute 4 };

topoNodeDBId ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNullId;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeDBIdBehaviour BEHAVIOUR DEFINED AS
            !This is a distinguished attribute of the topoNodeDB object.!;
      ;
      REGISTERED AS { em-topo-attribute 5 };

topoNodeDefaultMO ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeMO;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeDefaultMOBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the managed object that is used as the
            default MO for launching request templates.!;
      ;
      REGISTERED AS { em-topo-attribute 6 };

topoNodeDisplayStatus ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeDisplayStatus;
      MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
      BEHAVIOUR topoNodeDisplayStatusBeahviour BEHAVIOUR DEFINED AS
            !This attribute identifies the list of display status defined by
            users.  Each entry of the list is a pair of attribute ID and
            value (integer only).  One example is performance.  Allowed
            attribute ID is specified by topoDatabase::allStatus.!;
      ;
      REGISTERED AS { em-topo-attribute 7 };

topoNodeGeoLocation ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeGeoLocation;
      MATCHES FOR EQUALITY;
```

```
        BEHAVIOUR topoN deGeoLocationBehaviour BEHAVIOUR DEFINED AS
              !This attribute identifies the longitude and latitude of the topo
              node.  The default value is NULL.!;
        ;
        REGISTERED AS { em-topo-attribute 8 };

  topoNodeID ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeId;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeBehaviour BEHAVIOUR DEFINED AS
              !This is a distinguished attribute of the topoNode object.!;
        ;
        REGISTERED AS { em-topo-attribute 9 };

  topoNodeLayer ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeLayer;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeLayerBehavior BEHAVIOUR DEFINED AS
              !This attribute identifies the layer that the topo node is on.!;
        ;
        REGISTERED AS { em-topo-attribute 10 };

  topoNodeMOSet ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeMOSet;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeMOSetBehaviour BEHAVIOUR DEFINED AS
              !This attribute identifies the managed objects elsewhere in the
              management information tree that are represented by this topoNode
              object.!;
        ;
        REGISTERED AS { em-topo-attribute 11 };

  topoNodeName ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeName;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeNameBehaviour BEHAVIOUR DEFINED AS
              !This attribute can be used to provided a user-friendly label for
              the topoNode.!;
        ;
        REGISTERED AS { em-topo-attribute 12 };

  topoNodeParents ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodes;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeParentBehaviour BEHAVIOUR DEFINED AS
              !This attribute identifies the logical parent topoNodes of this
              topoNode.!;
        ;
        REGISTERED AS { em-topo-attribute 13 };

  topoNodePeers ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodes;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoNodePeersBehaviour BEHAVIOUR DEFINED AS
              !This attribute contains a list of all topoNode objects which are
              logically connected to this topoNode object.!;
        ;
        REGISTERED AS { em-topo-attribute 14 };

  topoNodePropagatedSeverity ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeSeverity;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodePropagatedSeverityBehaviour BEHAVIOUR DEFINED AS
              !This attribute specifies what propagated severity the topology
```

```
                node has.!;
        ;
        REGISTERED AS { em-topo-attribute 15 };

topoNodePropagateUp ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoBoolean;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodePropagatedBehaviour BEHAVIOUR DEFINED AS
                !This attribute specifies whether the topology node should
                propagate its state to its parents.!;
        ;
        REGISTERED AS { em-topo-attribute 16 };

topoNodeRpcAgentMO ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeMO
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeRpcAgentMOBehaviour BEHAVIOUR DEFINED AS
                !This attribute identifies the RPC agent object that is
                represented by this topoNode object.!;
        ;
        REGISTERED AS { em-topo-attribute 17 };

topoNodeSeverity ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoNodeSeverity;
        MATCHES FOR EQUALITY;
        BEHAVIOURtopoNodeSeverityBehaviour BEHAVIOUR DEFINED AS
                !This attribute specifies what severity the topology node has.!;
        ;
        REGISTERED AS { em-topo-attribute 18 };

topoNodeSnmpAgentMO ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeMO;
        MATCHES FOR EQUALITY;
        BEHAVIOURtopoNodeSnmpAgentMOBehaviour BEHAVIOUR DEFINED AS
                !This attribute identifies the SNMP Proxy Agent object that is
                represented by this topoNode object.!;

        ;
        REGISTERED AS { em-topo-attribute 19 };

topoNodeState ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoNodeState;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeStateBehaviour BEHAVIOUR DEFINED AS
                !This attribute specifies what the state of the topology node
                is.!;
        ;
        REGISTERED AS { em-topo-attribute 20 };

topoNodeType ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoNodeTypeId;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoNodeTypeBehaviour BEHAVIOUR DEFINED AS
                !This attribute identifies the topoType object in the topology
                database which describes the purpose and behaviour of this
                topoNode object.  This attribute may only be set to a new type
                which is derived from the existing type of the topoNode.!;
        ;
        REGISTERED AS { em-topo-attribute 21 };

topoStatePropagation ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoBoolean;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoStatePropagationBehaviour BEHAVIOUR DEFINED AS
```

```
                !This attribute identifies whether the state propagation should
                be performed for all topology nodes.!;
        ;
        REGISTERED AS { em-topo-attribute 22 };

topoTypeAllBaseOf ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoTypeAllBaseOfBehaviour BEHAVIOUR DEFINED AS
                !This attribute names the topoType objects that have this
                topoType object as a logical base class through any number of
                derivations.!;
        ;
        REGISTERED AS { em-topo-attribute 23 };

topoTypeAllDerivedFrom ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoTypeAllDerivedFromBehaviour BEHAVIOUR DEFINED AS
                !This attribute names the topoType objects that this topoType
                object is logically derived from through any number of
                derivations.!;
        ;
        REGISTERED AS { em-topo-attribute 24 };

topoTypeAllLegalArcs ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoTypeAllLegalArcsBehaviour BEHAVIOUR DEFINED AS
                !This attribute names the topoType objects that this topoType
                object can connect to, including those specified by any base
                types.!;
        ;
        REGISTERED AS { em-topo-attribute 25 };

topoTypeAllLegalChildren ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoTypeAllLegalChildrenBehaviour BEHAVIOUR DEFINED AS
                !This attribute names the topoType objects that this topoType
                object can contain, including those specified by any base
                types.!;
        ;
        REGISTERED AS { em-topo-attribute 26 };

topoTypeBaseOf ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
        MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
        BEHAVIOUR topoTypeBaseOfBehaviour BEHAVIOUR DEFINED AS
                !This attribute names the topoType objects that directly name
                this topoType object as a logical base class.!;
        ;
        REGISTERED AS { em-topo-attribute 27};


topoTypeDBId ATTRIBUTE
        WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNullId;
        MATCHES FOR EQUALITY;
        BEHAVIOUR topoTypeDBIdBehaviour BEHAVIOUR DEFINED AS
                !This is a distinguished attribute of the topoTypeDB object.!;
        ;
        REGISTERED AS { em-topo-attribute 28 };
```

```
topoTypeDefaultLayer ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypeDefaultLayer;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeDefaultLayerBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the default layer that is used by the
            topo node.!;
      ;
      REGISTERED AS { em-topo-attribute 29 };

topoTypeDerivedFrom ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
      MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
      BEHAVIOUR topoTypeDerivedFromBehaviour BEHAVIOUR DEFINED AS
            !This attribute names the topoType objects that this topoType
            object is logically derived from.!;
      ;
      REGISTERED AS { em-topo-attribute 30 };

topoTypeDrawMethod ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypeDrawMethod;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoTypeDrawMethodBehaviour BEHAVIOUR DEFINED AS
            !This attribute defines the drawable of the topoType object.!;
      ;
      REGISTERED AS { em-topo-attribute 31 };

topoTypeId ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypeId;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoTypeIdBehaviour BEHAVIOUR DEFINED AS
            !This attribute is the distinguished attribute for a topoType
            object.!;
      ;
      REGISTERED AS { em-topo-attribute 32 };


topoTypeLegalArcs ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
      MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
      BEHAVIOUR topoTypeMaxLegalArcsBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the topoTypes that may legally form
            arcs with this topoType.!;
      ;
      REGISTERED AS { em-topo-attribute 33 };

topoTypeLegalChildren ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypes;
      MATCHES FOR EQUALITY, SET-COMPARISON, SET-INTERSECTION;
      BEHAVIOUR topoTypeMaxLegalChildrenBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the topoTypes that may legally be
            children of this topoType.!;
      ;
      REGISTERED AS { em-topo-attribute 34 };

topoTypeMaxTopoLevel ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypeMaxTopoLevel;
      MATCHES FOR EQUALITY, ORDERING;
      BEHAVIOUR topoTypeMaxTopoLevelBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the highest abstract graph level that
            this node participates in the topology.  A topoNode may not have
            more than one arc to each abstract graph level higher than
            this.!;
      ;
      REGISTERED AS { em-topo-attribute 35 };
```

```
topoTypeMaxVisibleLevel ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoTypeMaxVisibleLevel;
      MATCHES FOR EQUALITY, ORDERING;
      BEHAVIOUR topoTypeMaxVisibleLevelBehaviour BEHAVIOUR DEFINED AS
            !This attribute identifies the highest abstract graph level that
            this node logically appears in.  A topoNode may not have any arcs
            to an abstract graph level higher than this.!;
      ;
      REGISTERED AS { em-topo-attribute 36 };

topoViewBackgroundImage ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoViewBackgroundImage;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoViewBackgroundImageBehaviour BEHAVIOUR DEFINED AS
            !This attribute contains the relative file name of a image to
            display in the view.!;
      ;
      REGISTERED AS { em-topo-attribute 37 };

topoViewDBId ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoNullId;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoViewDBIdBehaviour BEHAVIOUR DEFINED AS
            !This is a distinguished attribute of the topoNodeDB object.!;
      ;
      REGISTERED AS { em-topo-attribute 38 };

topoViewMapConfigFile ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoViewMapConfigFile;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoViewMapConfigFileBehaviour BEHAVIOUR DEFINED AS
            !This attribute is the file for vector (geographic) map
            configuration.!;
      ;
      REGISTERED AS { em-topo-attribute 39 };

topoViewMapInitialGeoArea ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoViewMapInitialGeoArea;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoViewMapInitialGeoAreaBehaviour BEHAVIOUR DEFINED AS
            !This attribute is to specify the initial zoom area of the
            geographical map.!;
      ;
      REGISTERED AS { em-topo-attribute 40};

topoViewNodePosition ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoViewNodePosition;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoViewNodePositionBehaviour BEHAVIOUR DEFINED AS
            !This attribute contains x,y coordinates of the topoNodeView
            image to be displayed in the view.!;
      ;
      REGISTERED AS { em-topo-attribute 41 };

topoNodeIsManaged ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoNodeManaged;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeIsManagedBehaviour BEHAVIOUR DEFINED AS
            !This attribute specifies the logical and of this nodes
            topoNodeManaged attribute with that of its parent's
            topoNodeIsManaged attribute.!;
      ;
      REGISTERED AS { em-topo-attribute 42 };
```

```
topoN deManaged ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoNodeManaged;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeManaged BEHAVIOUR DEFINED AS
            !This attribute specifies wheth r the topoNode should be managed
            by applications.!;
      ;
      REGISTERED AS { em-topo-attribute 43 };

topoNodeUserData ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.topoNodeUserData;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoNodeUserDataBehaviour BEHAVIOUR DEFINED AS
            !This attribute specifies a user defined data to be stored with
            the topoNode.!;
      ;
      REGISTERED AS { em-topo-attribute 44 };

topoViewNodeAutoPosition ATTRIBUTE
      WITH ATTRIBUTE SYNTAX EM-TOPO-ASN1.TopoBoolean;
      MATCHES FOR EQUALITY;
      BEHAVIOUR topoViewNodeAutoPositionBehaviour BEHAVIOUR DEFINED AS
            !This attribute specifies if at the creation time the position of
            the topoViewNode is automatically generated.!;
      ;
      REGISTERED AS { em-topo-attribute 45 };

-- Actions

topoNodeGetByName ACTION
      BEHAVIOUR topoNodeGetByNameBehaviour BEHAVIOUR DEFINED AS
            !This action returns the topoNodeId of the topoNode whose
            topoNodeName attribute matches the input name!;
      ;
      WITH INFORMATION SYNTAX EM-TOPO-ASN1.TopoNodeName;
      WITH REPLY SYNTAX EM-TOPO-ASN1.TopoNodes;
      REGISTERED AS { em-topo-action 1};

topoNodeGetByType ACTION
      BEHAVIOUR topoNodeGetByTypeBehaviour BEHAVIOUR DEFINED AS
            !This action returns a list of topoNodeIds of the topoNodes whose
            topoNodeType attributes match the input type!;
      ;
      WITH INFORMATION SYNTAX EM-TOPO-ASN1.TopoTypeId;
      WITH REPLY SYNTAX EM-TOPO-ASN1.TopoNodes;
      REGISTERED AS { em-topo-action 2 };

topoNodeGetByMO ACTION
      BEHAVIOUR topoNodeGetByMOBehaviour BEHAVIOUR DEFINED AS
            !This action returns a list of topoNodeIds of the topoNodes which
            represent the input managed object!;
      ;
      WITH INFORMATION SYNTAX EM-TOPO-ASN1.TopoNodeMO;
      WITH REPLY SYNTAX EM-TOPO-ASN1.TopoNodes;
      REGISTERED AS { em-topo-action 3 };

topoGetViewGraph ACTION
      BEHAVIOUR topoGetViewGraphBehaviour BEHAVIOUR DEFINED AS
            !This action returns the hierarchy of all topoViews!
      ;
      WITH INFORMATION SYNTAX EM-TOPO-ASN1.TopoNullId;
      WITH REPLY SYNTAX EM-TOPO-ASN1.TopoViewGraph;
      REGISTERED AS { em-topo-action 4 };
```

topo.asn1

```
EM-TOPO-ASN1 {
      iso(1) org(3) dod(6) internet(1) private(4) enterprises(1) sun(42)
      products(2) managed(2) em(2) newtopo(40)
}

DEFINITIONS ::=
BEGIN

IMPORTS
      ObjectInstance
 FROM CMIP-1 { joint-iso-ccitt ms(9) cmip(1) modules(0) protocol(3) };

em-topo OBJECT IDENTIFIER ::= {
      iso(1) org(3) dod(6) internet(1) private(4) enterprises(1) sun(42)
      products(2) management(2) em(2) topology(40)
}
em-topo-objectClass OBJECT IDENTIFIER ::= { em-topo 3 }
em-topo-binding OBJECT IDENTIFIER ::= { em-topo 6 }
em-topo-attribute OBJECT IDENTIFIER ::= { em-topo 7 }
em-topo-action OBJECT IDENTIFIER ::= { em-topo 9 }

---Default Values
nullTopoNodeMO topoNodeMO ::= null : NULL
emptyTopoNodeMOSet TopoNodeMOSet ::= { }
emptyTopoAllStatus TopoAllStatus ::= { }
emptyTopoAllLayer TopoAllLayer ::= { }
defaultDrawMethod TopoTypeDrawMethod ::= circle
nullGeoLocation TopoNodeGeoLocation ::= null : NULL
defaultTopoTypeDefaultLayer TopoTypeDefaultLayer ::= "default"
emptyLayer TopoNodeLayer ::= ""
emptyTopoNodeDisplayStatus TopoNodeDisplayStatus ::= { }
defaultMaxVisibleLevel TopoTypeMaxVisibleLevel ::= 0
defaultMaxTopoLevel TopoTypeMaxTopoLevel ::= 0
defaultTopoTypes TopoTypes ::= { }
defaultBackgroundImage TopoViewBackgroundImage ::= ""
defaultMapConfigFile TopoViewMapConfigFile ::= ""
defaultMapInitialGeoArea TopoViewMapInitialGeoArea ::= null:NULL
topoBolleanTrue TopoBoolean ::= TRUE
topoBooleanFalse TopoBoolean ::= FALSE
emptyUserData TopoNodeUserData ::= ""

TopoNullId ::= NULL

TopoAllStatus ::= SET OF GraphicString

TopoAllLayer ::= SET OF GraphicString

TopoBoolean ::= BOOLEAN

TopoNodeId ::= INTEGER (0..4294967295)

TopoNodeState ::= INTEGER (0..4294967295)

TopoNodeSeverity ::= INTEGER (0..4294967295)

TopoNodeMO ::= CHOICE {
      object  ObjectInstance,
      null    NULL
}

TopoNodeMOSet ::= SET OF ObjectInstance
```

```
TopoNodeName ::= GraphicString

TopoNodes ::= SET OF TopoNodeId

TopoNodeDisplayStatus ::= SET OF SEQUENCE {
      status      GraphicString,
      value       INTEGER
}

TopoNodeLayer ::= GraphicString

TopoNodeGeoLocation ::= CHOICE {
      null      NULL
      value     SEQUENCE {
                   latitude    REAL,
                   longitude   REAL
            }
}

TopoNodeUserData ::= GraphicString

TopoTypeId::= Graphicstring

TopoTypeMaxVisibleLevel ::= INTEGER (-32768..32767)

TopoTypeMaxTopoLevel ::= INTEGER (-32768..32767)

TopoTypes ::= SET OF TopoTypeId

TopoTypeDrawMethod :: = ENUMERATED {
      circle              (0),
      square              (1),
      rectangular         (2),
      triangle            (3),
      hexagon             (4),
      line                (5)
}

TopoTypeDefaultLayer ::= GraphicString

TopoViewNodePosition ::= SEQUENCE {
      x     INTEGER,
      y     INTEGER
}

TopoViewBackgroundImage ::= GraphicString

TopoViewMapConfigFile ::= GraphicString

TopoViewMapInitialGeoArea ::= CHOICE {
      null  NULL
      area  SEQUENCE {
                  centerLatitude  REAL,
                  centerLongitude REAL,
                  widthInKm       REAL

            }
}

TopoNodeManaged ::= BOOLEAN

TopoNodeData ::= SEQUENCE {
      id       TopoNodeId,
      name     TopoNodeName
```

```
}

TopoViewGraphNode ::= SEQUENCE {
        node            TopoNodeData,
        parents         SET OF TopoNodeData
}

TopoViewGraph ::= SET OF TopoViewGraphNode

END
```

Claims

1. A computer network comprising:

   a plurality of network nodes and interconnections;
   a network management system comprising a database of managed network resources, said database of managed network resources defining network nodes, associated node types and associated views of said nodes, the system being operable to modify said views based on user input changes in attributes of said nodes; and
   a plurality of network management users, said network management users being arranged to display views of said network using said network management database.

2. A computer network as claimed in claim 1 wherein said attributes of said nodes comprise parent relationships, and the system being arranged to form a new view node each time a new parent is added to an attribute of a node.

3. A computer network as claimed in claim 2 wherein the system is arranged to delete a view node each time a parent is deleted from attributes of a node.

4. A computer network as claimed in claim 1, 2 or 3 wherein said parent relationships include logical and physical parent relationships.

5. A computer network as claimed in claim 1, 2, 3 or 4 comprising a network viewer on a plurality of user workstations, so that said user workstations can form views of said network based on said database of managed network resources.

6. A computer network as claimed in any one of the preceding claims wherein said network nodes are defined by a node database object class. said node database object class containing node objects, a type database object class, said type object class containing network object types, and a view database object class, said view database object class containing view objects of said network.

7. A computer network as claimed in claim 6 wherein said nodes are associated with a severity, wherein alarms posted for a particular node are propagated to selective views of said network.

8. A computer network as claimed in claim 1 wherein views of said network are created by said network management system when a new node is added to said system.

9. A computer network as claimed in any one of the preceding claims and including one or more storage media conveying software defining said database and a network administration program, said network administration program modifying said views of said nodes based on user input of changes in attributes of said nodes.

10. A method of managing a computer network comprising:

    forming an object oriented database of managed network resourc s, said database of managed network r - sourc s comprising network nodes. associated node types and associated vi ws of said nodes;
    displaying a plurality of vi ws of said network using said database of managed network resourc s; and
    modifying said vi ws based on user input changing said nodes in said database of managed network

11. A method as claimed recited in claim 10 and comprising the steps of:

defining parent relationships of said nodes; and
forming new views based on additions of parents to a node.

12. A method as claimed in claim 11 and comprising deleting a view node when a parent is deleted from a node.

13. A method as claimed in claim 10, 11 or 12 wherein said step of forming an object oriented database of managed network resources comprises the steps of:

forming a node type class containing a plurality of node type objects;
forming a node type class containing a topogrophy of nodes in said network; and
forming a view type class containing views of objects in said network.

14. A method as claimed in claim 10, 11, 12 or 13 and comprising the step of defining alarm severity for at least one node in said database, said severity defining when alarms are propagated to other nodes in a view of said network.

15. One or more storage media conveying software comprising:

a database of managed network resources, said database of managed network resources comprising network nodes, network node types, and views of said nodes; and
a network administration program, said network administration program modifying said views of said nodes based on user input of changes in attributes of said nodes.

16. A method as claimed in claim 9 or media as claimed in claim 15, the software comprising a network viewing program, said network viewing program being operable to display various views of said network based on user selection input.

17. A method as claimed in claim 9 or 16 or media as claimed in claim 15 or 16, the software comprising an alarm propagation system, said alarm propagation system being operable to propagate alarms in views of said network based on propagation severities associated with said nodes.

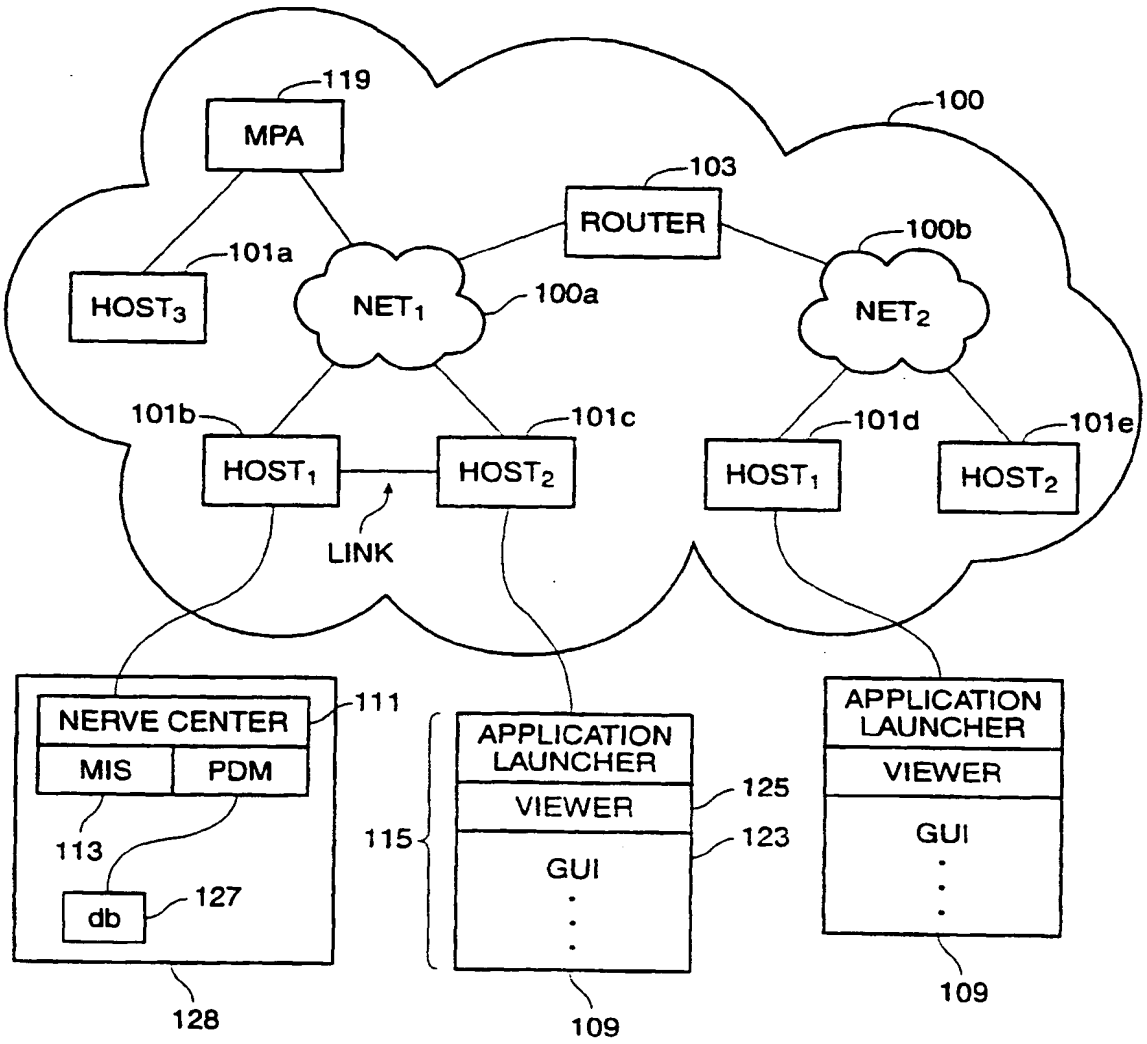

FIG. 1

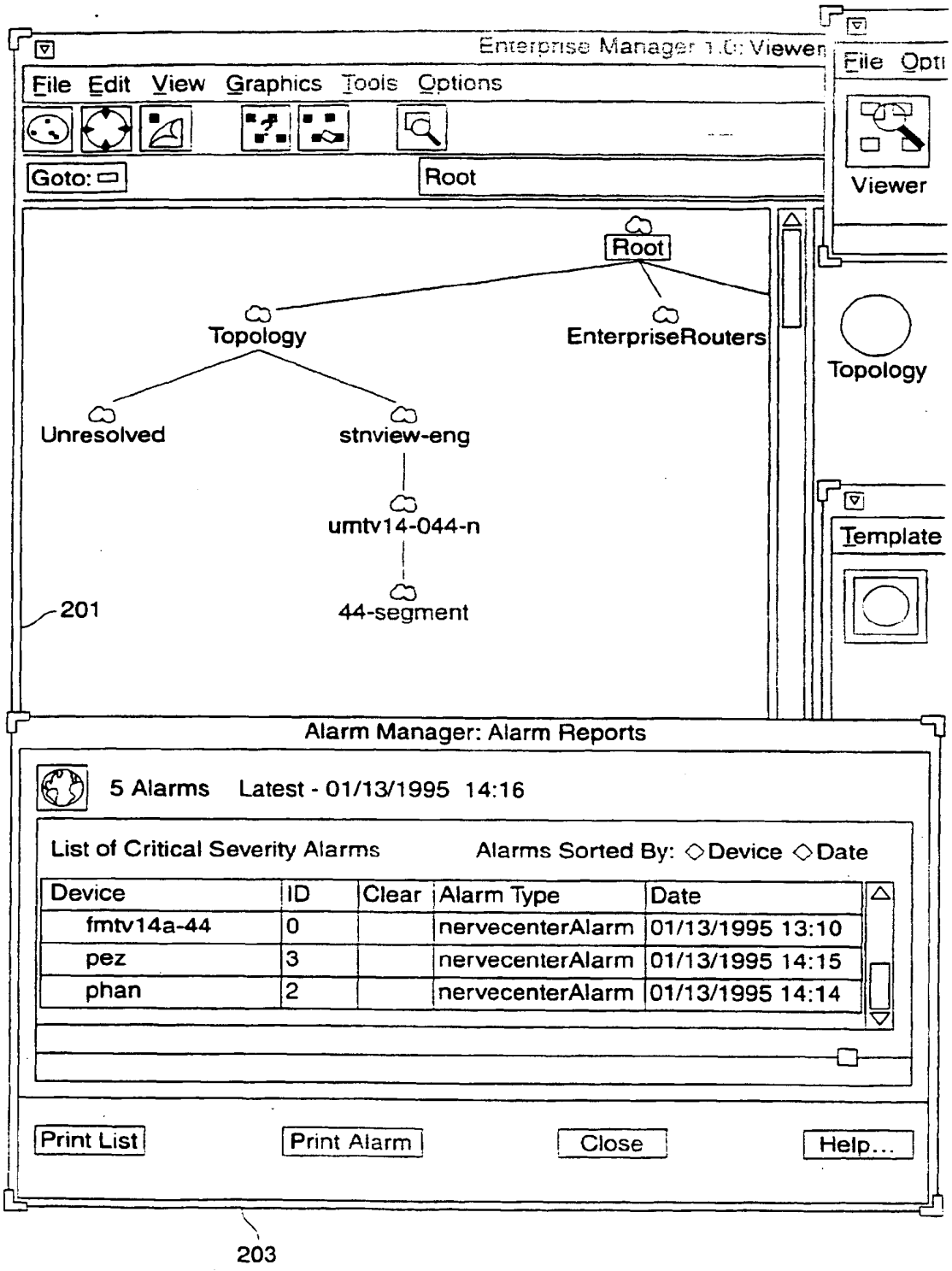

FIG. 2

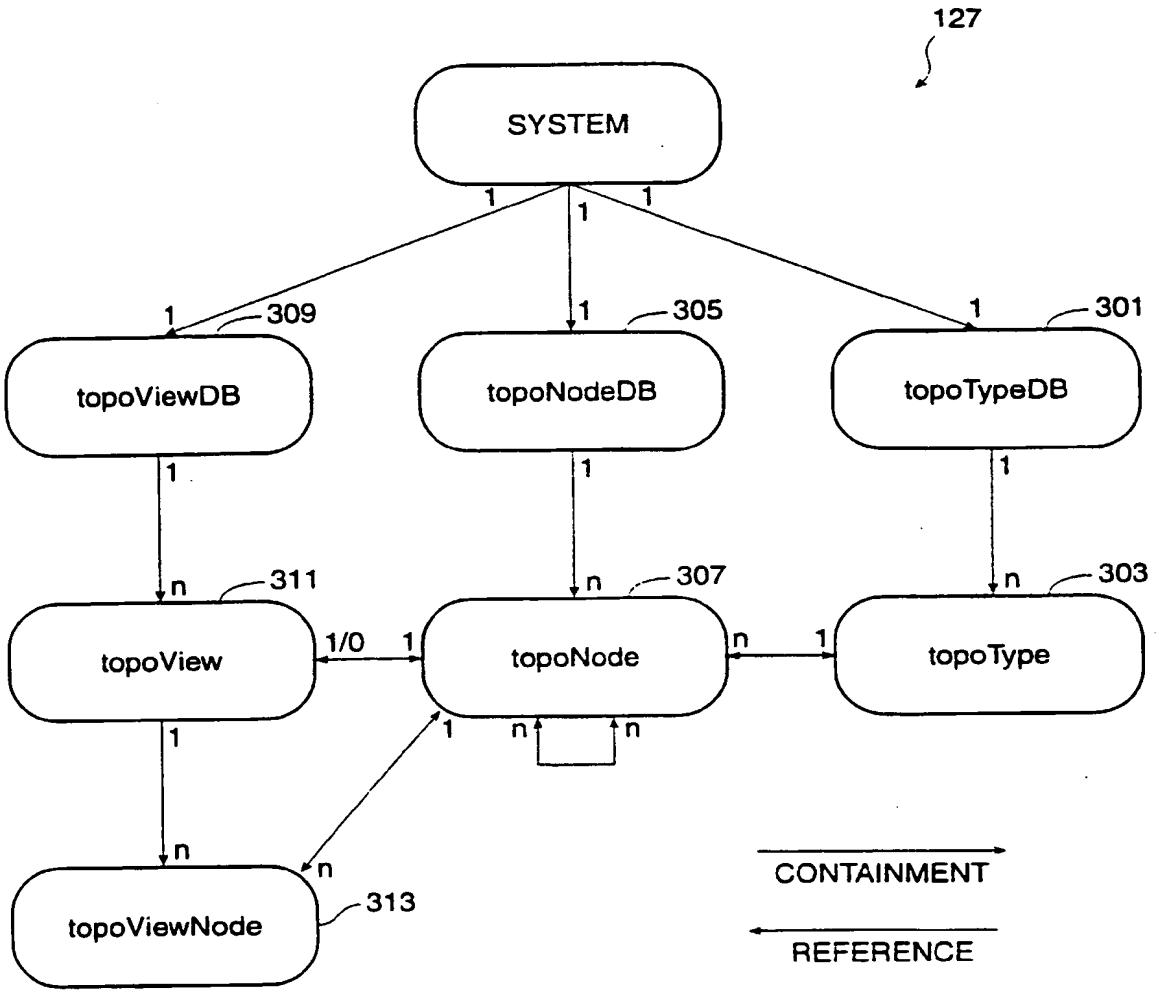

FIG. 3

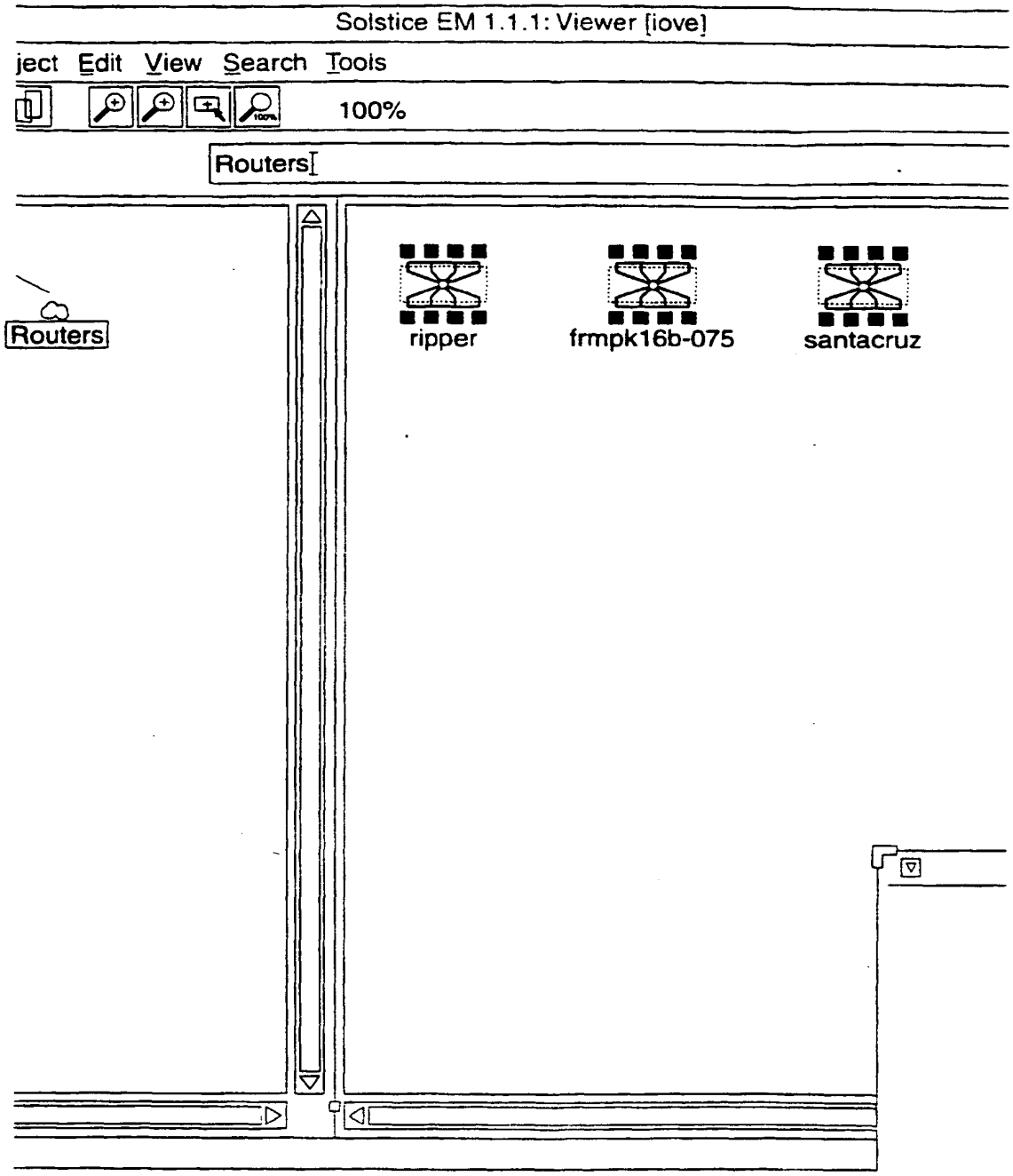

FIG. 4A

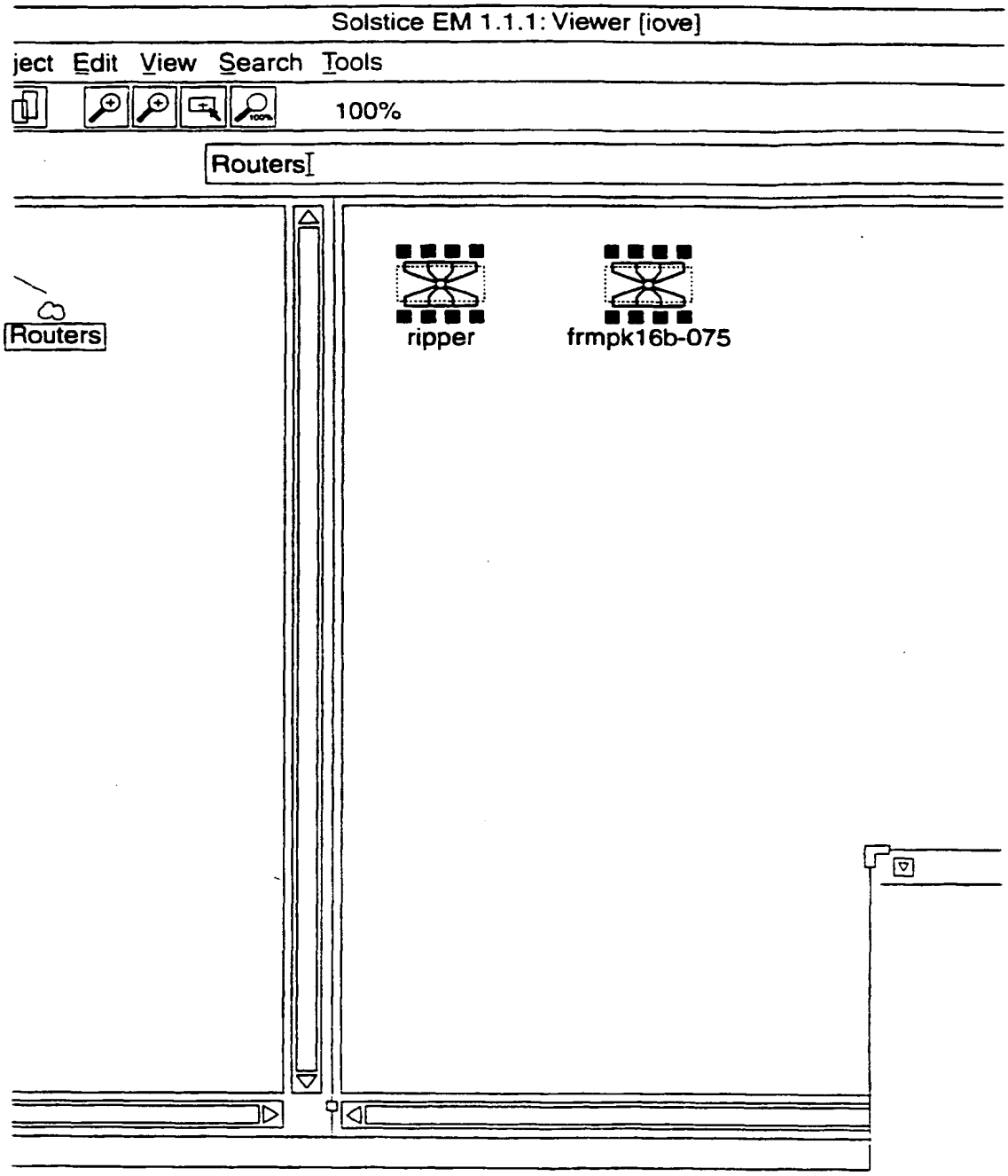

FIG. 4B

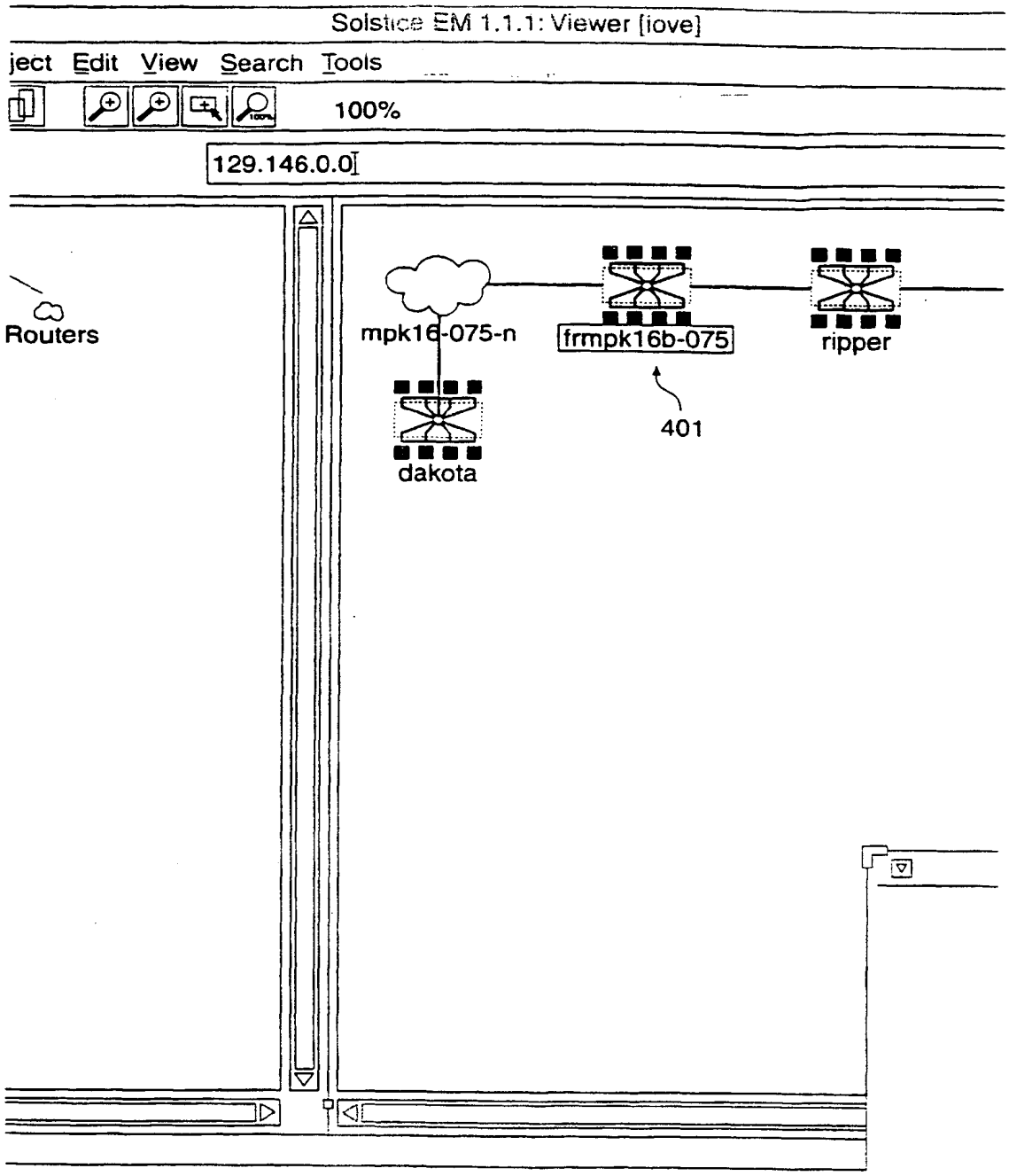

FIG. 4C

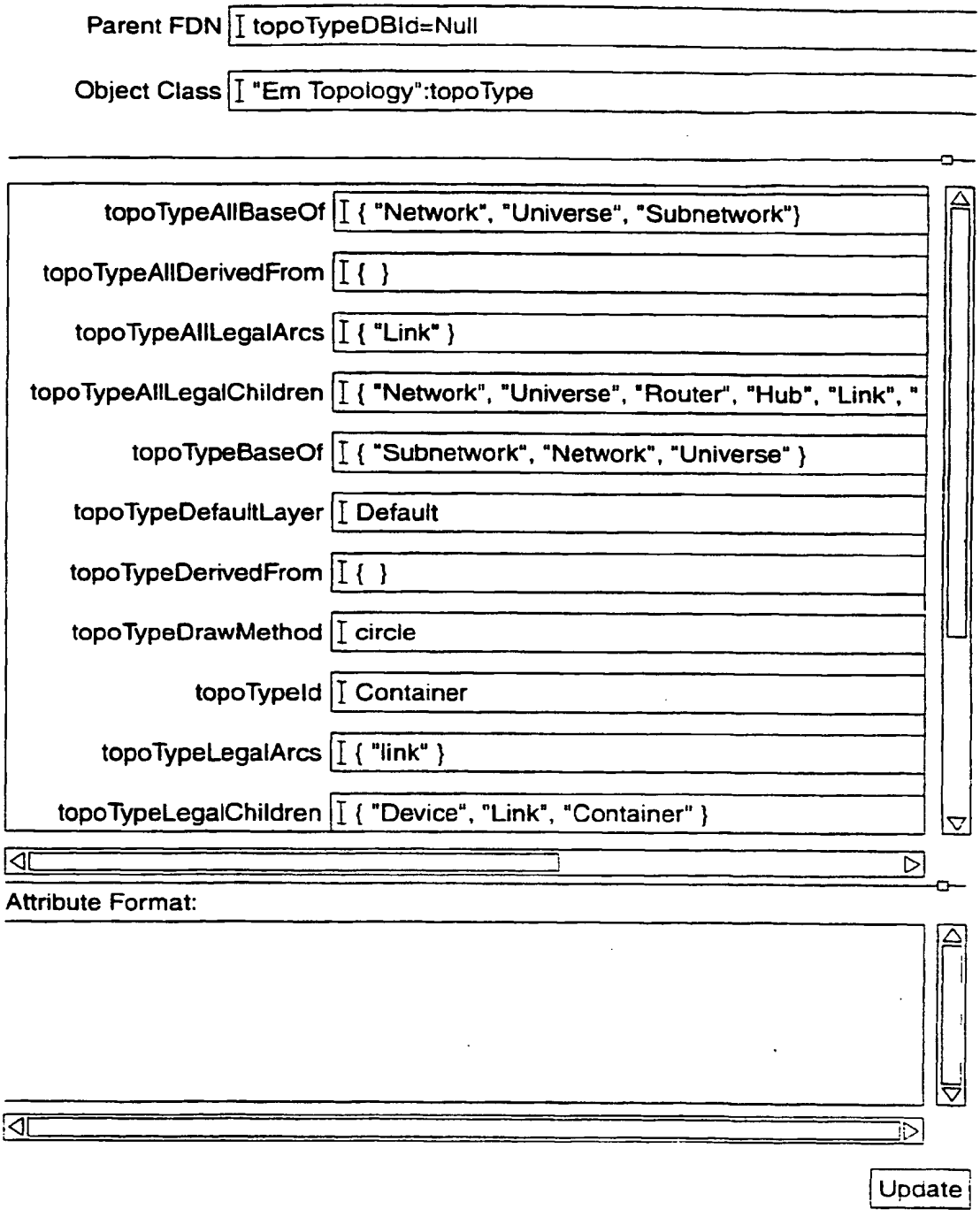

FIG. 5A

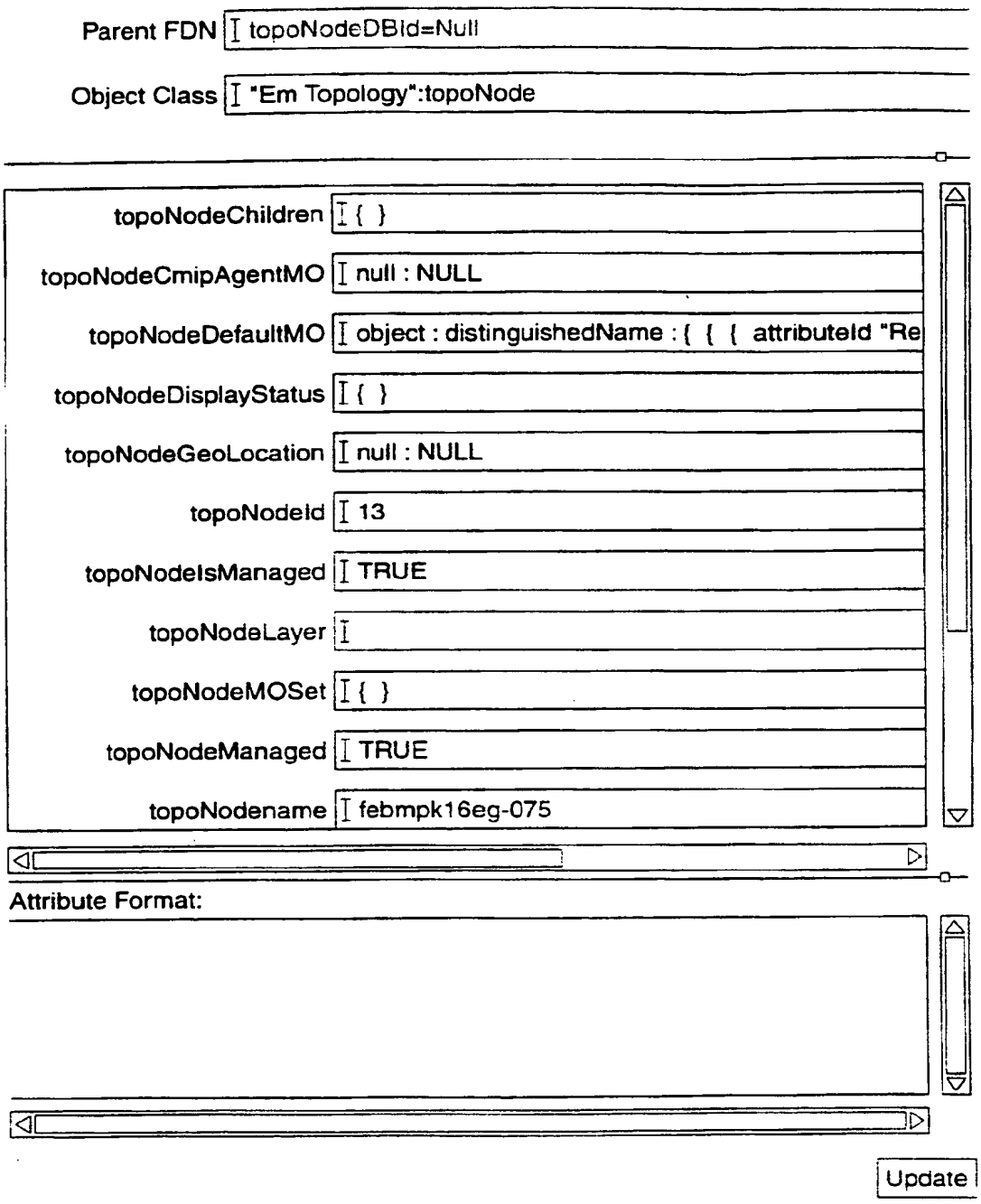

FIG. 5B

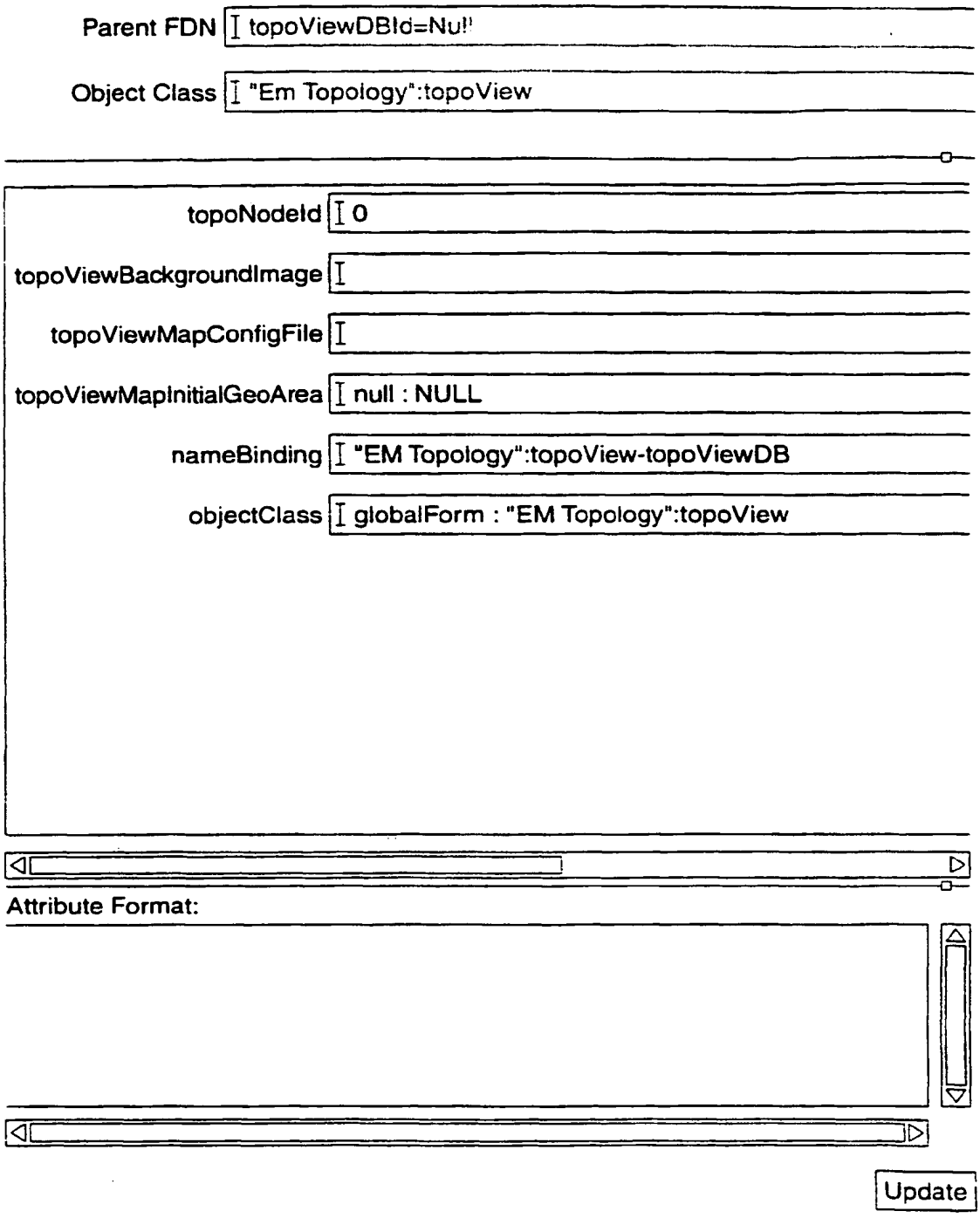

FIG. 5C

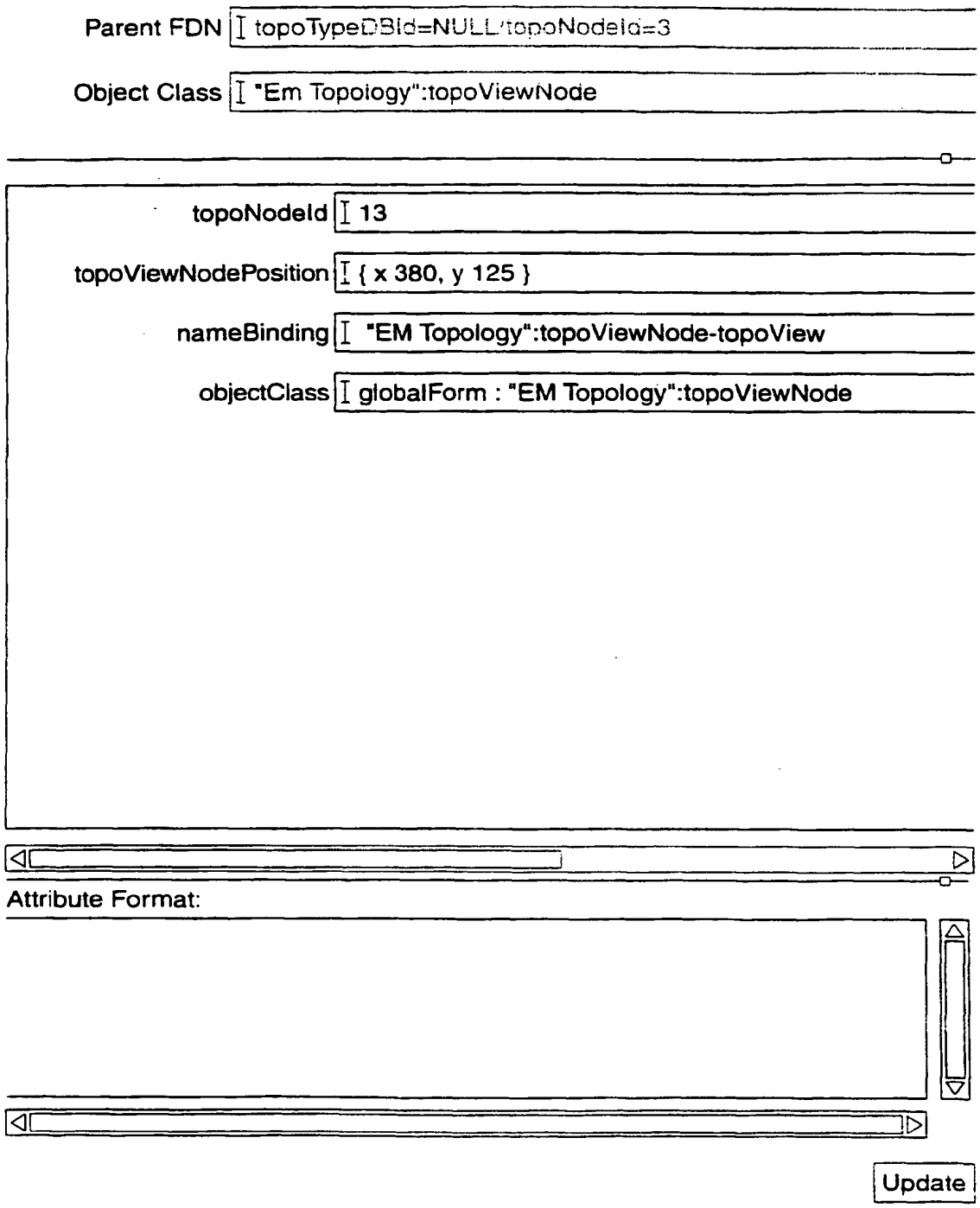

FIG. 5D

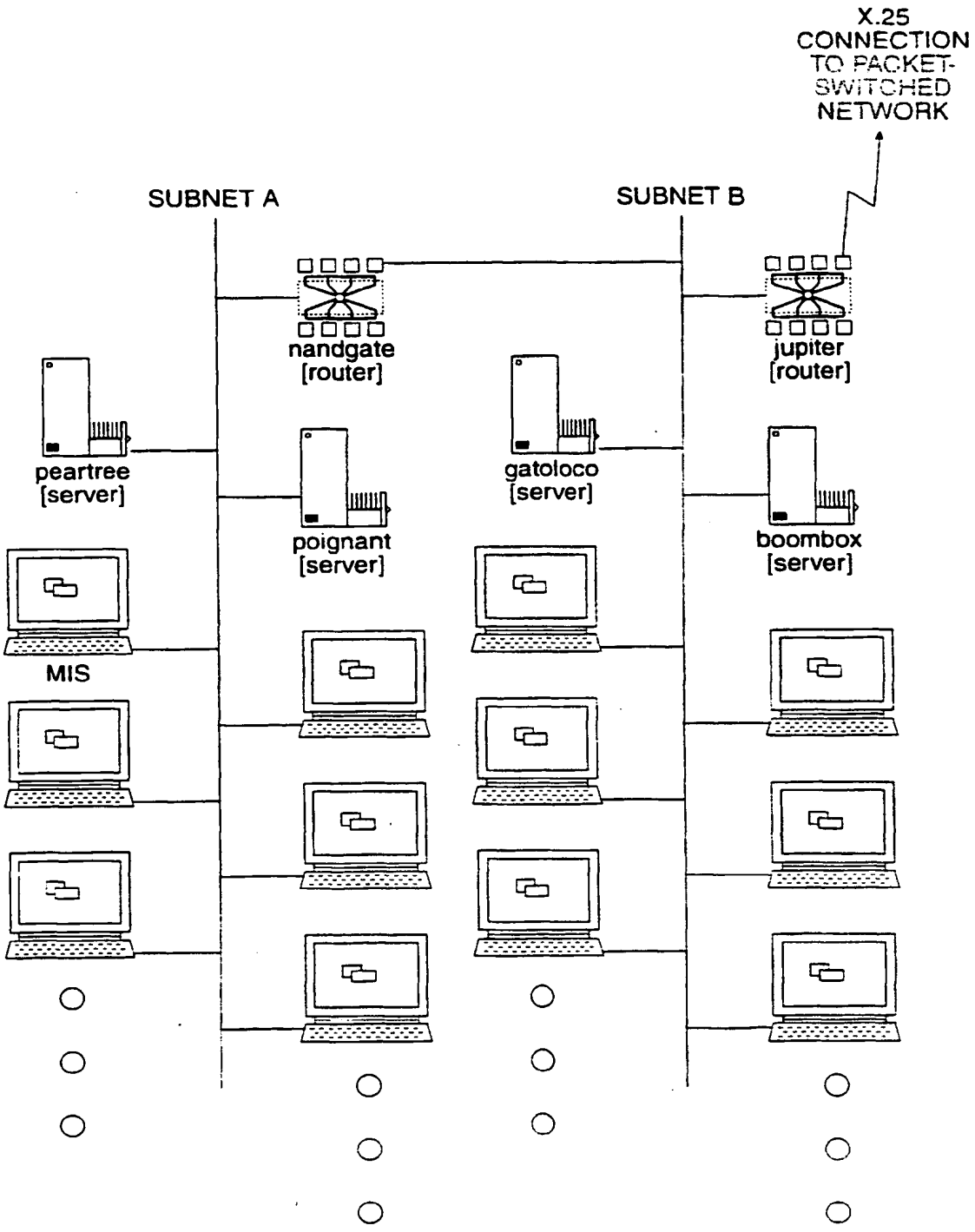

FIG. 6A

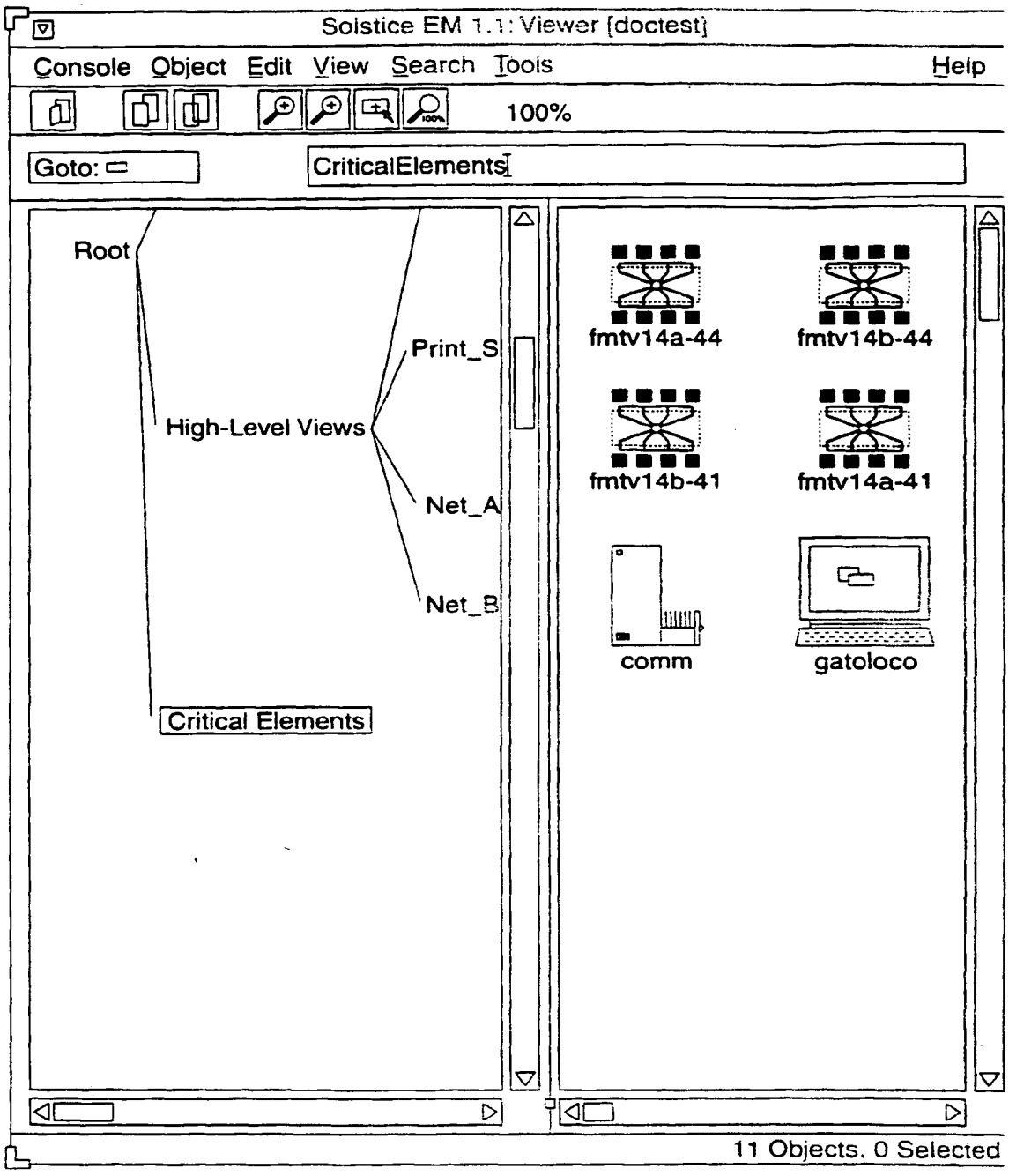

FIG. 6B

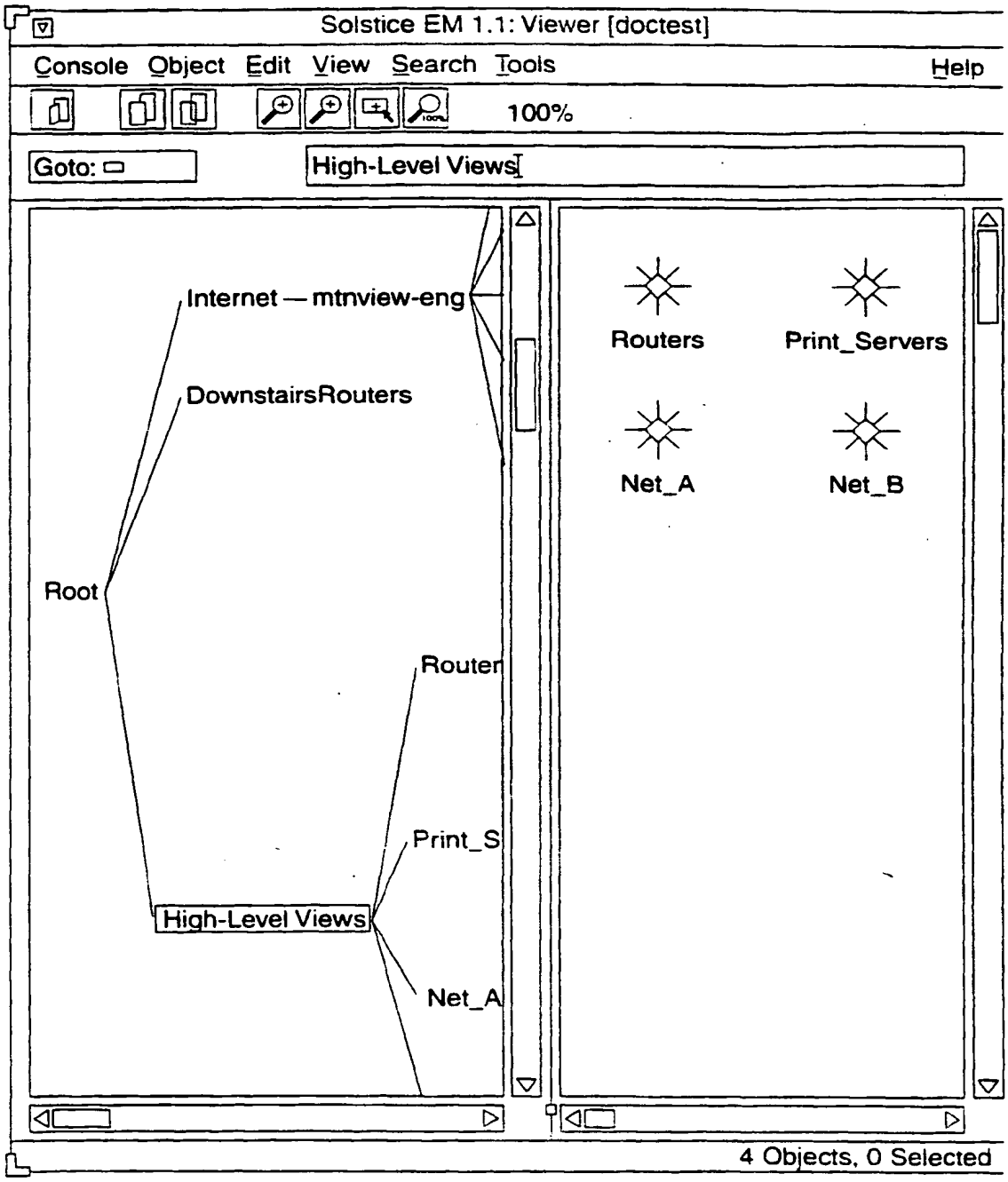

FIG. 6B

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(54) Network topology management system

(57) A system and method for maintaining complex relationships between computer network elements provides a common database for storing node, type, and view data. The views are created and maintained by the network management system. When a new node is added or parentage of a node is changed, the views of a node are modified in a network database.

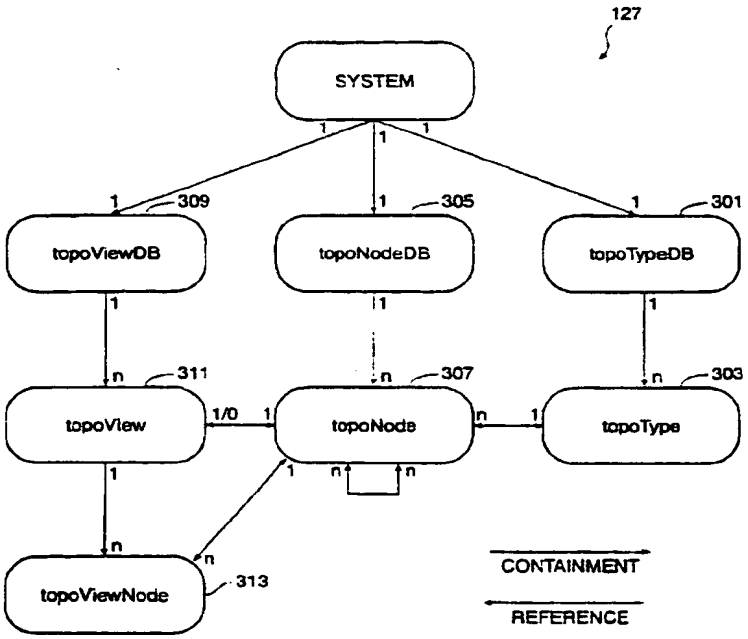

FIG. 3

EP 0 773 649 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 96 30 7993

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A	WO 92 05485 A (CABLETRON SYSTEMS INC) 2 April 1992 (1992-04-02) * abstract * * page 3, line 12 - page 5, line 29 * * page 7, line 1 - page 18, line 11 * * page 23, line 21 - page 24, line 14 * * page 29, line 17 - page 35, line 6 * * page 37, line 1 - page 39, line 17 *	1,8-10, 14-17 2	H04L12/24 H04Q3/00
A	DUPUY A: "NETMATE: A NETWORK MANAGEMENT ENVIRONMENT" IEEE NETWORK: THE MAGAZINE OF COMPUTER COMMUNICATIONS,US,IEEE INC. NEW YORK, vol. 5, no. 2, 1 March 1991 (1991-03-01), pages 35-40,43, XP000207780 ISSN: 0890-8044 * abstract * * page 35, left-hand column, line 1 - page 39, left-hand column, line 23 *	1,5,9, 10,15,16	
X A	EP 0 457 445 A (HEWLETT PACKARD CO) 21 November 1991 (1991-11-21) * abstract * * column 1, line 1 - column 4, line 45 * * column 6, line 4 - column 9, line 17 * * page 2 *	10 1,8,9, 15,16	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04L H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	13 November 2000	Lievens, K

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13-11-2000

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